On the Scientific Foundations of Level 2 Fusion

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This Keynote speech will actually address two focal topics: (1) certain suggestions for extensions and modifications of the well-known "JDL"Data Fusion process model, and (2) perspectives on an overarching approach toward developing first Theories and then Algorithms for Level 2 Data Fusion.

1.0 EXTENSIONS AND MODIFICATIONS TO THE JDL DATA FUSION MODEL

The JDL Data Fusion process model has certainly served the Data Fusion (DF) community well as a means for describing and understanding the nature of the DF information process. It has not however been recently reviewed as regards application to the framework of a distributed information and fusion environment. Distributed Data Fusion (DDF) will no doubt form one important underpinning for the realization of Network-Centric Warfare, and it is in this motivational context that the preliminary ideas herein are offered. Certain other ideas involving some suggested modifications of the model are also offered. The (incomplete) suggestions are shown in Slide 4 in the Keynote presentation. There are two categories of suggestions as just remarked, one for the DDF condition and one regarding new thoughts for an improved specification and characterization of the DF process.

1.1 Extensions Regarding DDF

Four major extensions are suggested: one related to the "Pedigree" function, one related to an "Adjudication" function, one related to the need for both local fusion and network-based fusion algorithms, and one related to the sharing of information across the nodes of the network. The Pedigree function is defined as comprising those sub-functions and items of information necessary to maintain formal mathematical (or, generally, algorithmic) integrity for fusion of the received information at the receiving node. The Adjudication function comprises those sub-functions necessary to address internodal conflict in fused state estimates (eg as required to arbitrate and evolve the "Common Operating Picture"). These functions are shown notionally in Slide 4 as they would be involved in internodal processing in a DDF architecture. Note that we see the Pedigree function as necessary for both the internodal exchange of either measurements or fused state estimates, whereas the Adjudication function is presumed only applicable to the exchange of fused estimates. We suggest making obvious the fact that in a netted environment there will typically be a need for two classes of fusion processing, one for local fusion (eg of node-organic sensor data), and one to fuse the local information or estimates with that received from the network. Finally, we characterize the overall processes involved with internodal sharing of data or information as "Information Sharing Strategies or ISS"; these

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functions contain whatever logic necessary to govern the protocols by which nodes decide to send particular information to other nodes or to broadcast it, etc. That is, the ISS is the logic which determines “who gets what information, how rapidly, in what form, etc”.

1.2 Modifications of Basic DF Processing

We also see a deficiency in the current JDL model characterization regarding the role of quality control, and inter-level processing. A frequent criticism of the model is that it appears to hint at sequential processing; this of course was never intended but admittedly does come across in the diagrammatic construct of the model. We suggest to repair this by making obvious the need for internodal bilevel processing, as shown in Slide 4. We also envision a two-step qulaity control process before a node issues an estimate: one that checks whether a just-formed estimate is of adequate quality (if not a Level 4 directive for additional information might be issued, for example), and what we label as a “Belief Revision”process that checks for both internodal consistency and consistency with recent global estimates.

Lastly, we suggest that the basic DF model be modified to make obvious the co-processing of both inductively-based and deductively-based inferencing processes. This suggestion is driven by the new need for addressing problems in which the degree of a priori knowledge about adversarial behavior is very limited such as terrorism problems and the variety of asymmetric warfare problems. We are not the first to suggest this; as noted in Slide 6, Waltz has previously suggested the need for co-processing of Data Mining and Data Fusion operations.

2.0 PERSPECTIVES ON AN OVERARCHING APPROACH TOWARD DEVELOPING FIRST THEORIES AND THEN ALGORITHMS FOR LEVEL 2 DATA FUSION

The views that are depicted in Slides 9 onward offer some ideas for moving forward in framing a formalized approach to dealing with Level 2 fusion problems. The suggestions revolve initially about the assertion that part of the fusion community’s problem in making headway in both scientific understanding of Level 2 concepts, in development of Theories related to Level 2, in algorithmic specification, and then application-oriented accomplishments is that we have not been adequately specific in the characterization of the elements of “situational constructs”. Slide 11 argues this point, in noting that the terms shown there are (more or less) as specific as we have been in describing what Level 2 is about. The need for specificity is thought to follow directly from the fact that, if we are to estimate Level 2 states of interest, we must define what those states are. In the end, we see this as a need for an Ontological specification of Level 2 state elements. An ontological specification is in itself an Existential Theory, as it is descriptive of how we see the real (truth) world for any Level 2 application. We then remark on the qualites of a Theory (Slides 17,18) and, drawn from the Ontological literature, suggest how Ontology may help in the framing of necessary theories (Slide 19). It is suggested in Slide 20 that progress has been made at Level 1 without formalized ontological analysis because the real-world concepts are adequately specific and adequately well-understood such that engineering theories and algorithms can be nominated to form desired state estimates. In Slide 21 we argue that that is not the case for Level 2. The next Slides through Slide 30 discuss the important interaction (yet to be better or well-understood) between formalized processes by which application and user-specific information needs are defined (such as by Cognitive Work Analysis, CWA), and the formalisms of Ontological specification. These two related but not equivalent approaches to detailed specification of the information elements of a Level 2 conceptualization must be harmonized in some way; ie we must be able to relate “user language”to “ontological language”. Slides 31 and 32 simply depict the concern that if we must develop mission-specific

ontologies (as the ontological community suggests that practical ontologies are of course application-specific), then there is a scope problem of constructing a wide base of ontologies.

Slides 33 onward to Slide 52 review a variety of works in the literature that specifically address various of the basic notions we have so far (withoput a proper ontology) ascribed to Level 2; these slides point out that there is a body of theoretical literature that exists that in fact attempts, albeit not in the defense applications of interest here, to offer various formalisms to deal with situational states, behaviors of individuals and groups, with human intentionality, etc. It is suggested and remarked that the fusion community has apparently not drawn possibly-relevant ideas for its own purposes from these possibly-helpful theoretical foundations. Summarizing in Slide 53, we suggest that, following the formation of a relevant ontology, there would be suggested various relevant theories for describing the relationships among situational components and their attributes that can then be used as a basis for eventual algorithm development. Earlier, in Slides 20 and 21, we have asserted the distinction between Theories and Algorithms in that theories are descriptive of the real world in a context that is unconstrained by limits of observability, whereas algorithms are in essence approximations to the theories governed by or constrained by particular observational limitations.

On the Scientific Foundations of Level 2 Fusion

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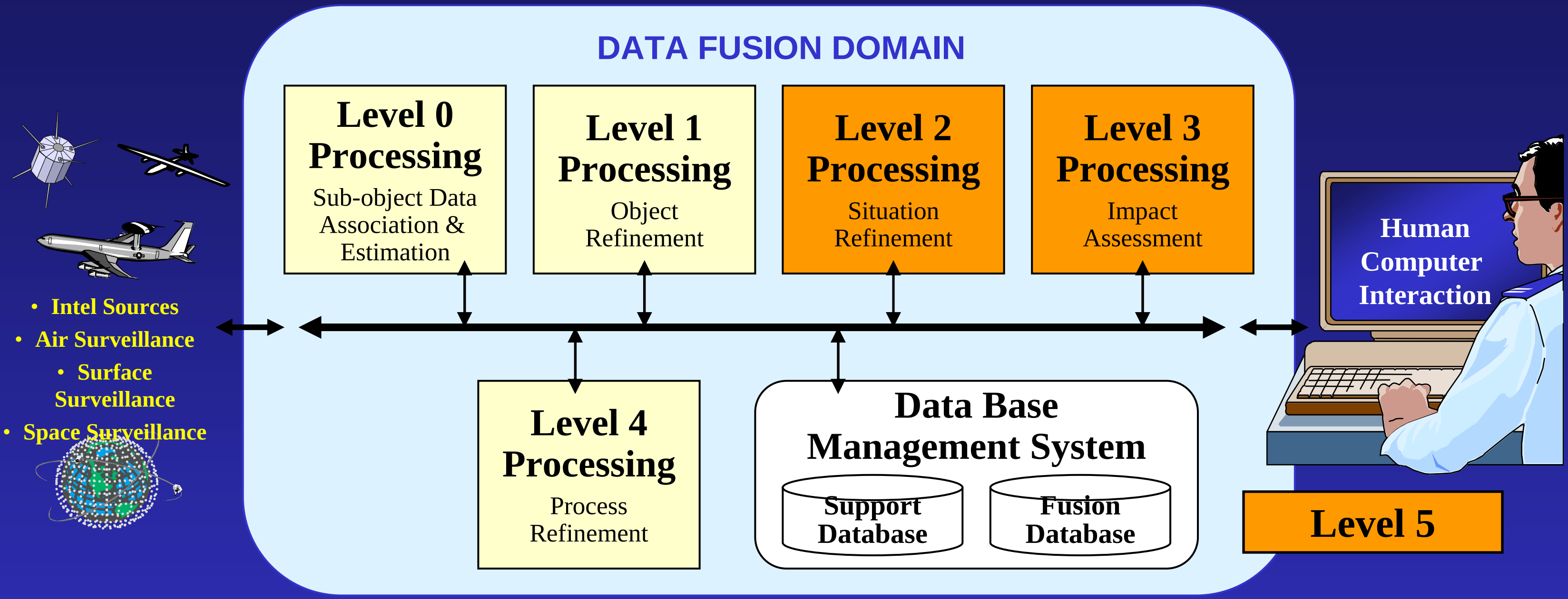
Discussion Topics

- Remarks on the Fusion Process Model
- Remarks on Level 2 Information Fusion Theories

Data Fusion Process Model



Level 0 — Sub-Object Data Association & Estimation: pixel/signal level data association and characterization

Level 1 — Object Refinement: observation-to-track association, continuous state estimation (e.g. kinematics) and discrete state estimation (e.g. target type and ID) and prediction

Level 2 — Situation Refinement: object clustering and relational analysis, to include force structure and cross force relations, communications, physical context, etc.

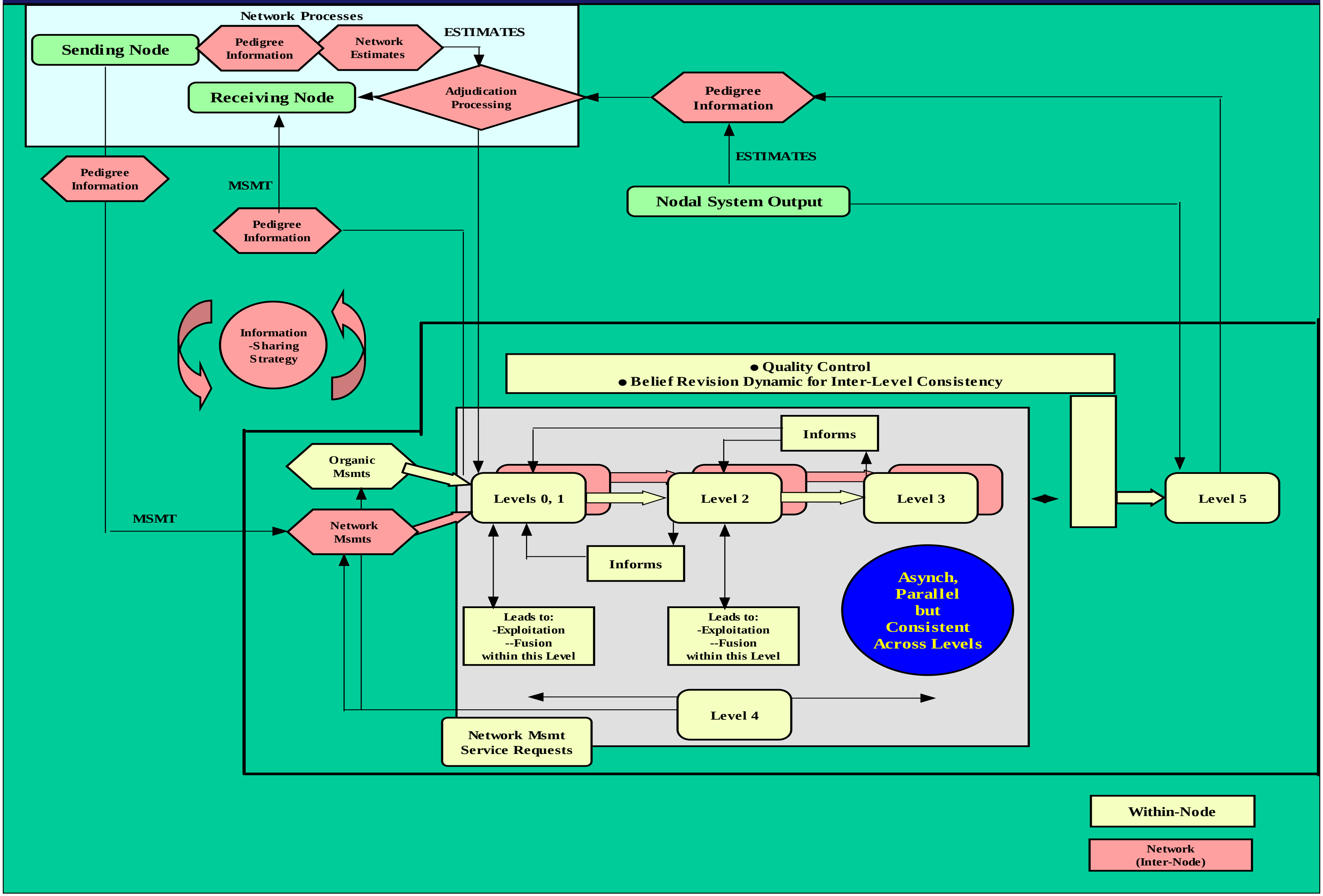
Level 3 — Impact Assessment: [Threat Refinement]: threat intent estimation, [event prediction], consequence prediction, susceptibility and vulnerability assessment

Level 4: Process Refinement: adaptive search and processing (an element of resource management)

Level 5: Human-Fusion Process Interface

Extensions to the Distributed Case

KN2-4



Extensions to the Distributed Case

- New Components of the Model:
  - Formalization, at least conceptually, of the nature of the **Inter-Level processes, and subsequent Within-Level *Exploitation and Fusion*** processes
  - Formalization of the means by which overall (multi-Level) **Process *Quality and Consistency*** is maintained
  - Formalization of the conceptual nature of both ***Adjudication and Pedigree*** processes for Distributed Data Fusion
  - Formalization of the nature of internodal ***Information-Sharing Strategies***
  - **Specification of *Node-specific and Inter-Nodal Algorithm pairings***
- A Data Fusion **Process Ontology**

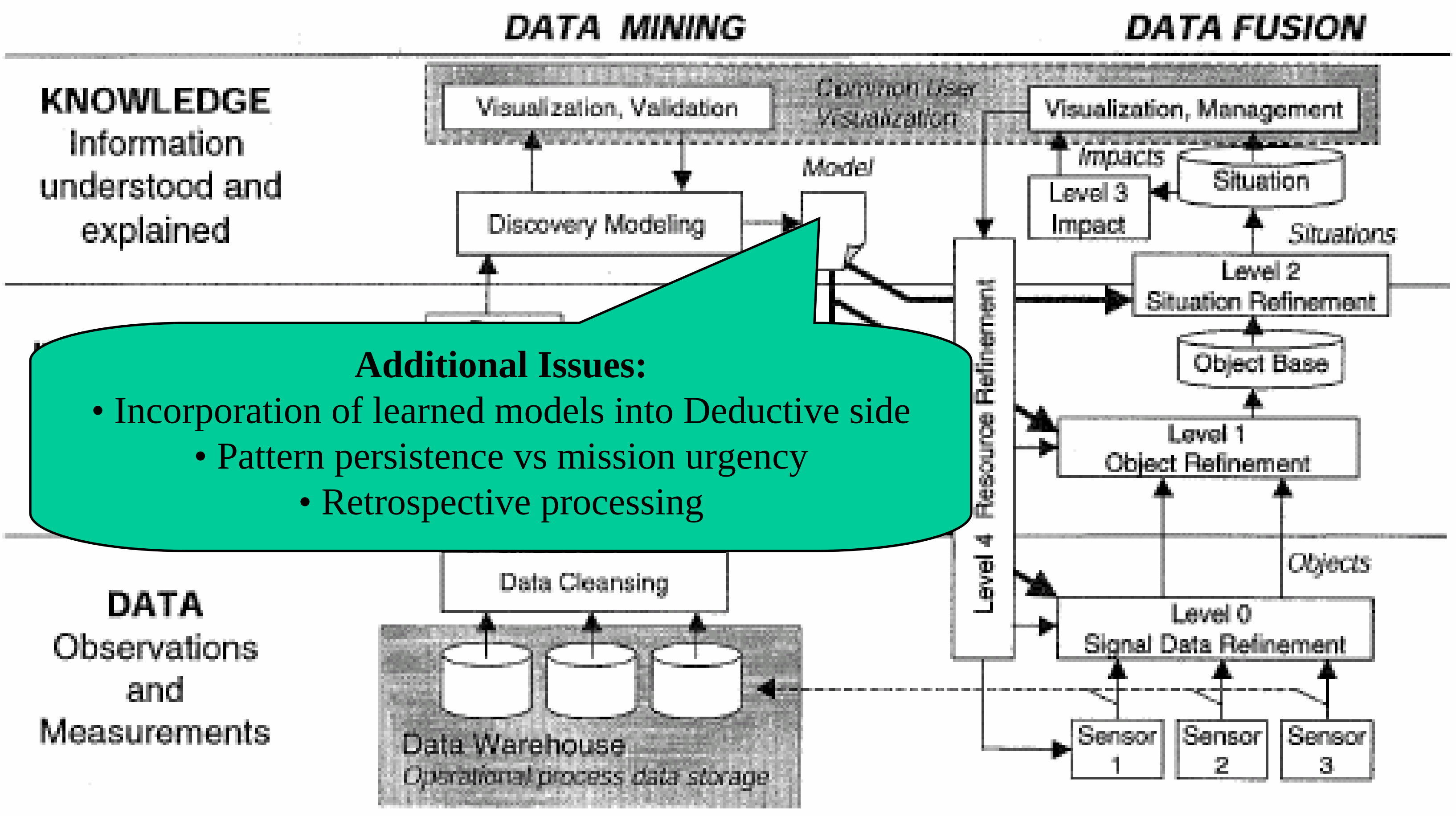
One Further Thought:
Combining Inductive/Abductive & Deductive Processes*

Table 2 - Comparison of Data Fusion and Data Mining Processes

Process:	DATA MININC	DATA FUSION
Knowledge Created	**Discovery** of the *existence* of previously unrecognized patterns associated with entities or events in time or space	**Detection** of the *presence* of known entity or event types in time or space applying previously learned models
Input Data	**Pre-Operational**- Statistically large collection of representative data containing observations of known targets with ground truth	**Operational** - Data collected by multiple sensors and sources
Reasoning Process	**Abduction-Induction**: Discovery of sufficient correlated relationships in data to infer a general *description* (or rule set) that may be always or generally (to some quantified degree) true	**Deduction:** Detection of previously known patterns in data to infer the *presence* and *identity* of the entity or event represented by that pattern
Knowledge Patterns (Models) Used	**Unknown**: (general) model of "interesting" data properties is used as template to detect qualifying candidates for "new" models of targets of interest	**Known**:(specific) models are used as templates to detect similar patterns in data.
Object of Detection/ Discovery Process and **Knowledge Gained**	• **Discovery** of "interesting" general relationships and patterns of behavior, which may be, validated as general models of relationships or behavior. • **Discovery** of new types of entities or events, by previously unidentified and unknown patterns, in large volumes of data	• **Detection** of individual and related sets of entities and events. • **Detection** of the presence, type and location of known types of entities or events in large volumes of data
Output Knowledge	**Models** of relationships or behaviors to describe target entities or events	**Detected targets** based on matching sensor data with known models of entities or events

* Waltz, E., "Information Understanding: Integrating Data Fusion and Data Mining Processes", 1998

One Thought on a Composite Architecture *



Additional Issues:

- Incorporation of learned models into Deductive side
- Pattern persistence vs mission urgency
- Retrospective processing

* Waltz, E., "Information Understanding: Integrating Data Fusion and Data Mining Processes", 1998

Combining Inductive/Abductive & Deductive Processes

- New Components of the Model Related to Inductive/Abductive Processes:
  - “L0”: Data preparation, cleansing, alignment
  - “L1”: Data Mining Pattern Search
  - “L2”: Knowledge/Model Discovery
  - Model Quality Control
    - Qualification metrics
  - Model Integration
- Issue: Human Role in this process

Scientific Foundations of Level 2 Fusion

What is Level 2 Fusion About?

"Situation Estimation"

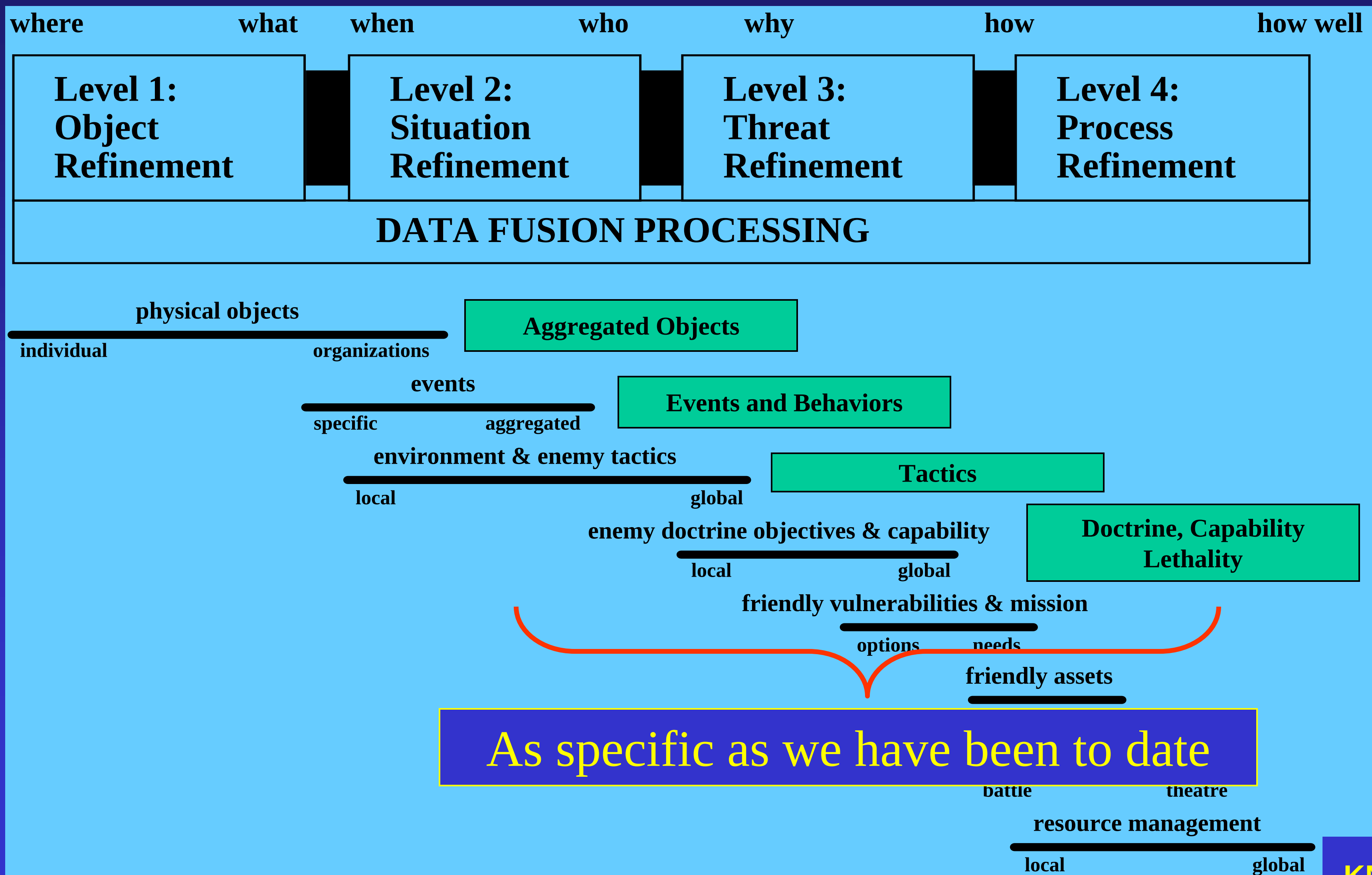
Estimates about Relationships among and Activities involving Physical and Non-physical "Objects" in the Real-World as Observed by the System at Hand

"Events and Behaviors"

"Aggregation"

The JDL Historical View of the Nature of Fusion Products across Levels

(R. Antony, circa 1989)



An Assertion

- The lack of specificity and formal analysis in these characterizations prevents mounting a consistent, scientifically-grounded approach to L2 algorithm development

The Starting Point for Algorithm Development:

Understanding the Real-World:

The need for a L2 Ontology

Why should the DF Community be Concerned with Ontology?

- If we are to have Theories about and (later) Algorithms to estimate "States" of interest about objects and activities in a problem space, we must be able to describe, represent, and specify those States in the Real World in some orderly way
- It is the same problem the community faced early on, when developing an initial Taxonomy
- It is what allows us to understand what is meant by the "Level 1" terms:
  - Tracks, maneuvers, classes/types of object identity, "move-stop-move behaviors, intersensor bias, air corridor, etc
    - Not as estimated from noisy observables but the concepts/notions **as exist in truth (at least initially)**

Value of an Existential Theory *

"A sound and complete (existential) theory E will ensure that

inconsistencies and ignorance in our data fusion system

derive from our system's knowledge of the world, and not

from the meaning of the terms by which the system

describes the world. (ie our existential ontology)"

* Lambert, D., "Grand Challenges of Information Fusion", FUSION2003, Cairns, Australia, July 2003

Theories, Algorithms, Models, and Ontology

On Theories *

- **Nature of a Theory**
  - A statement about ***relationships***
  - An ***explanation*** of a phenomenon
  - Possibly a statement about ***constraints or limiting conditions***
- **Criteria for a Theory**
  - Verifiability thru experimentation (Falsifiability)
  - Internal consistency, coherence
  - Parsimonious
  - Explanatory capability

* K. Shaver, “Validity in Research”, Lecture at College of William & Mary

Inconsistency in Theories *

- “There are ***two main types of inconsistency*** concerning a theory in physical sciences: Formal inconsistency, and factual inconsistency.
- Formal inconsistency arises when the theory has two or more hypotheses that contradict one another. Formal inconsistencies can be divided in two categories: Logico-mathematical, and conceptual.
  - ***Logical inconsistencies*** are easier to detect and are usually eliminated in the early development of a theory by logical operations (e.g. by deleting one of the contradicting hypotheses).
  - ***Conceptual contradictions are more difficult to identify and eliminate. They come into notice in the later stages of theory development.*** “

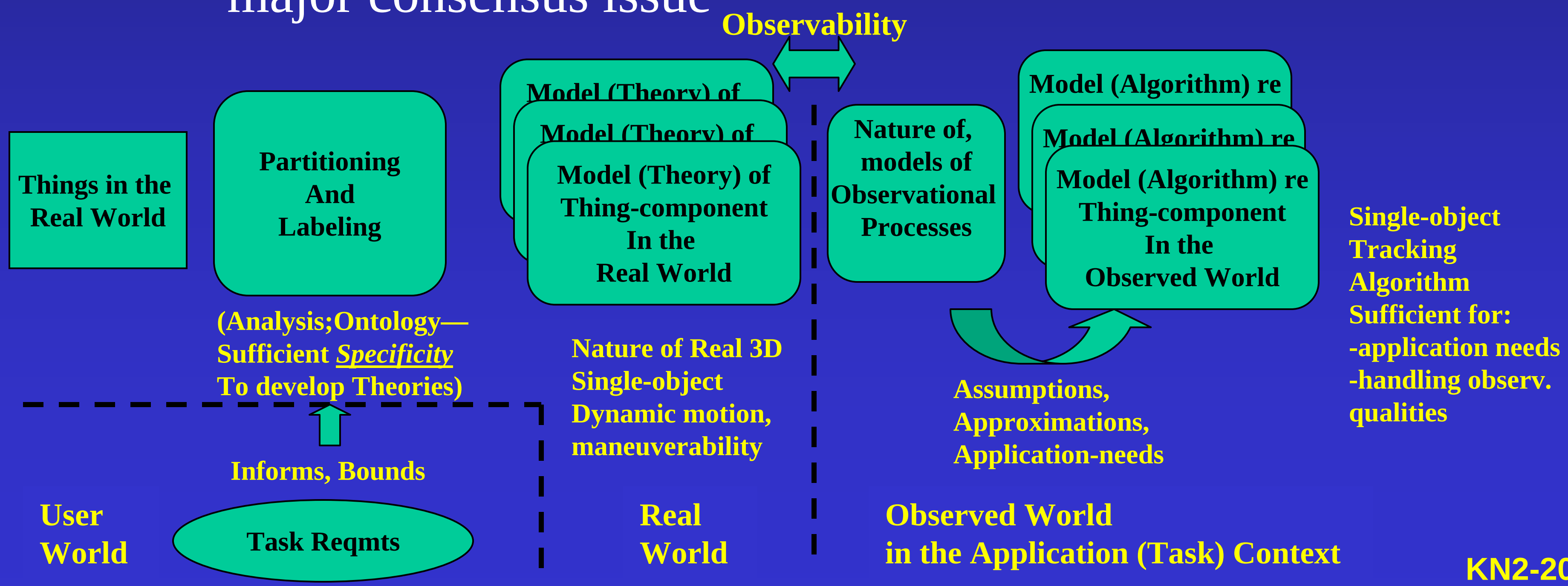
* Kocabas, S., Symp. On Computational Discovery of Communicable Knowledge, Stanford Univ, Mar., 2001

Theory Development and Ontology: How does Ontology help?

- Clarity in describing the real-world
- Consistent, shareable descriptive framework
- Organized framework for describing relationships—axiomatically-based

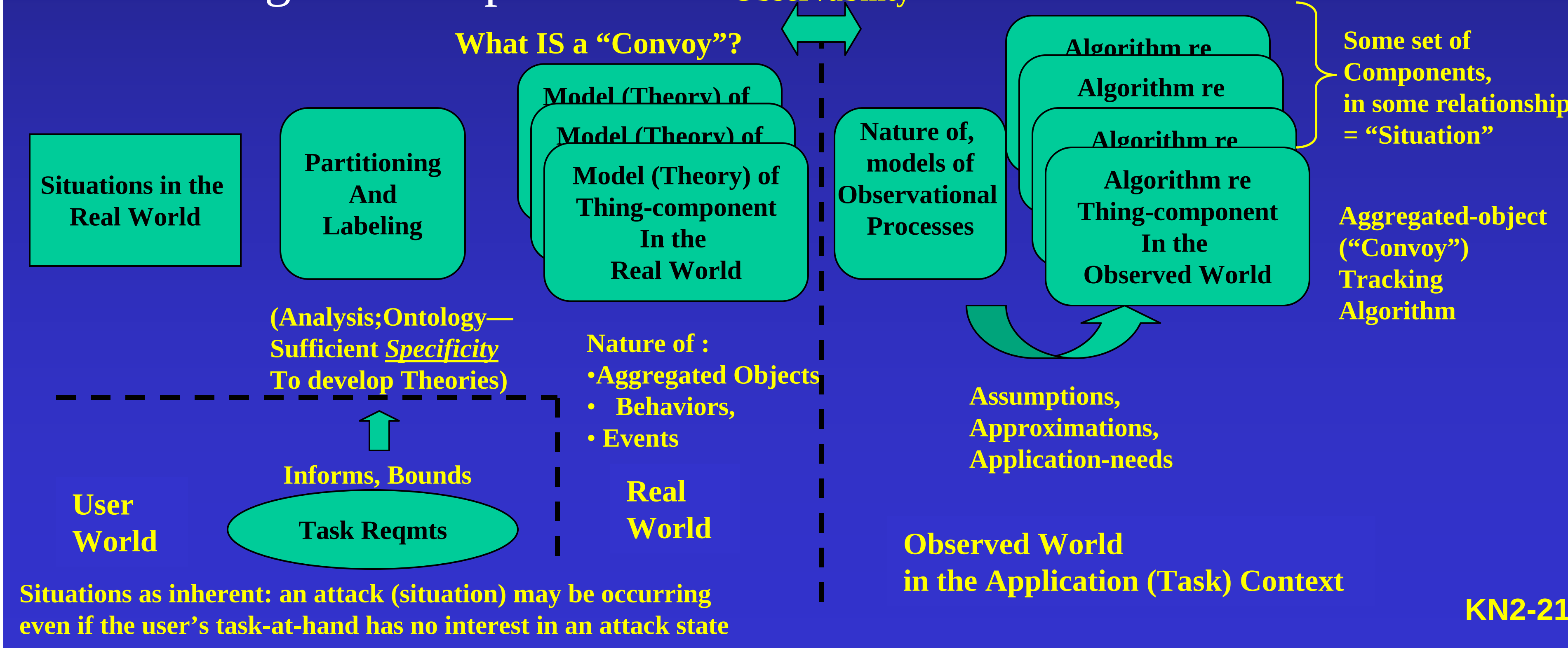
What about a L1 Ontology?

- The fusion community has succeeded without a (formal) L1 ontology because the concepts, as we have characterized them, are :
  - ***sufficiently precise to engineer to*** in the sense of algorithms and other engineering aspects (eg visualization)
  - ***(relatively) well-understood in common use***—thus no major consensus issue



What about a L2 Ontology?

- What is a "Situation"? --Not adequately specific
  --No common understanding
- How is it "Refined" --No metrics/quality measures
- What kind of algorithmic process yields a "Situation Estimate"?
- Llinas assertion: "Situation" is ***too coarse/abstract to engineer to***— MUST get more specific



Algorithm Development

- Algorithm development is a process that has its foundation first in a ***mentally-grounded or scientifically-grounded Theory*** and the associated descriptive language about how things are--*in truth*--in the Real World
- It is about formulating a ***numerical or symbolic approach to estimating or representing*** some features/some relationship about things in the Real World (an approximation to or model of)—or to employ a Theory about things or concepts in the Real World
- Later in development of an Algorithm, we must deal with:
  – Imperfect/flawed observations
  – Other application-specific factors
  – Implementation in a cost-effective, efficient, computational framework
  – etc

More on Models and Modeling *

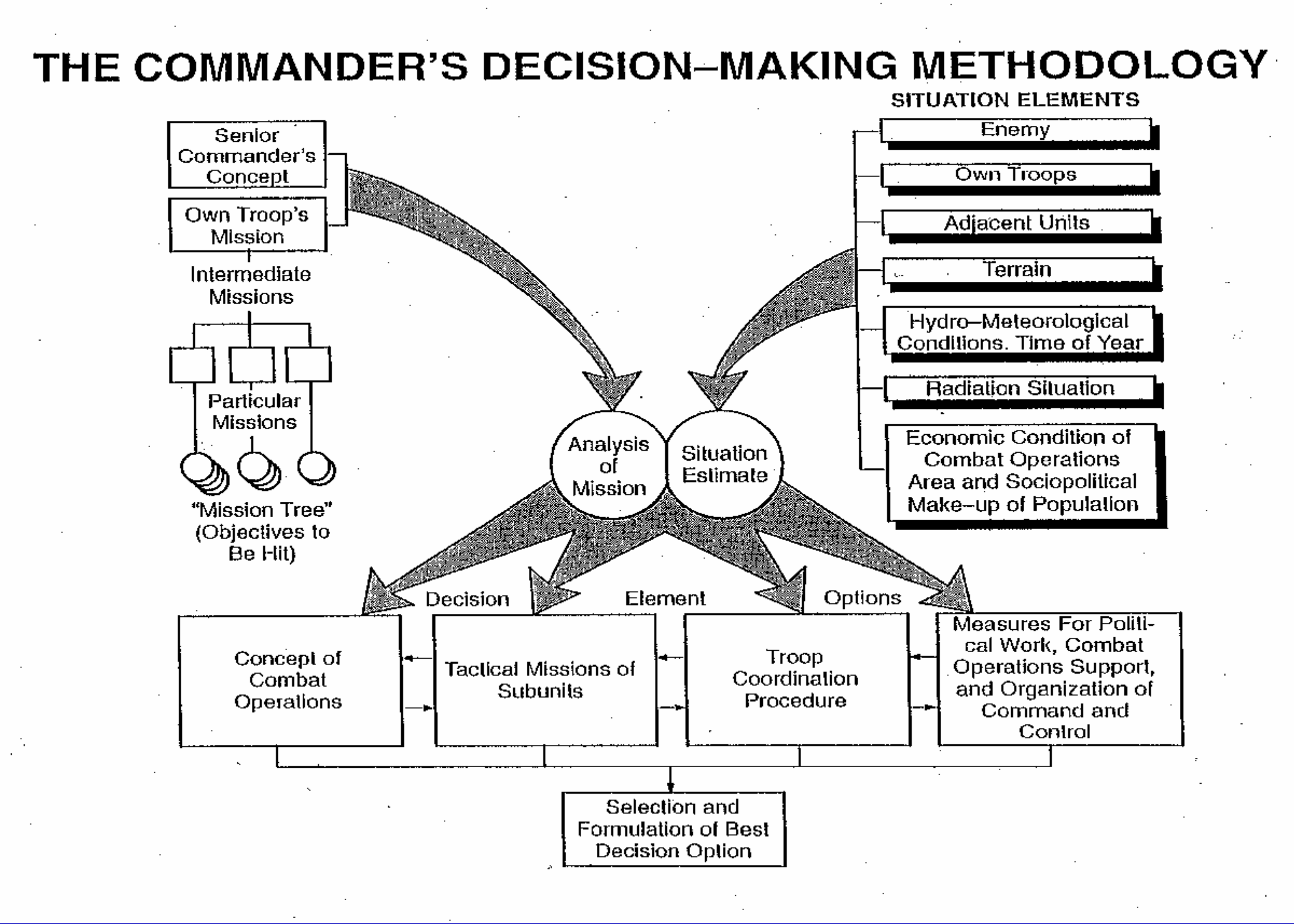
- Models are (idealized) analogs of the phenomena that they represent.
- “Models are not literal copies of that which they represent. Rather, they are conceptual tools for selecting and organizing salient features such as ***structural elements and their relationships, processes, and functions”***
  - Ontologies give us a framework for such “salient features”
- “Scientists construct and use models for a variety of purposes: a) to make the “invisible” overt or visible, b) **to articulate the structure and function of their theories** by specifying the elements of models and their spatial, temporal, and functional relationships, c) to explain phenomena or empirical data, d) to make predictions, and e) to communicate ideas.”
  - Models, built upon salient features (possibly) derived from Ontologies, articulate theories of science
- “Thus, the ability to construct and reason with models is widely regarded as the core of “doing” science.”

* Gilbert, S. W. (1991). Model building and a definition of science. *Journal of Research in Science Teaching, 28*, 73-79.

Getting Started

- Ok, *<u>if</u>* we agree that we must first address, ontologically, some range of concepts in the Real World somehow delineated by (Informed by) intuitive notions of either "Situations" or "Threats", how do we bound it? What's "in" and what's "out"?
- The problem of "Admission"
  - Must come from/be bounded by Missions, Goals, Objectives, Tasks
    - To bound the problem
    - To focus the work in a pragmatic, utility-oriented way

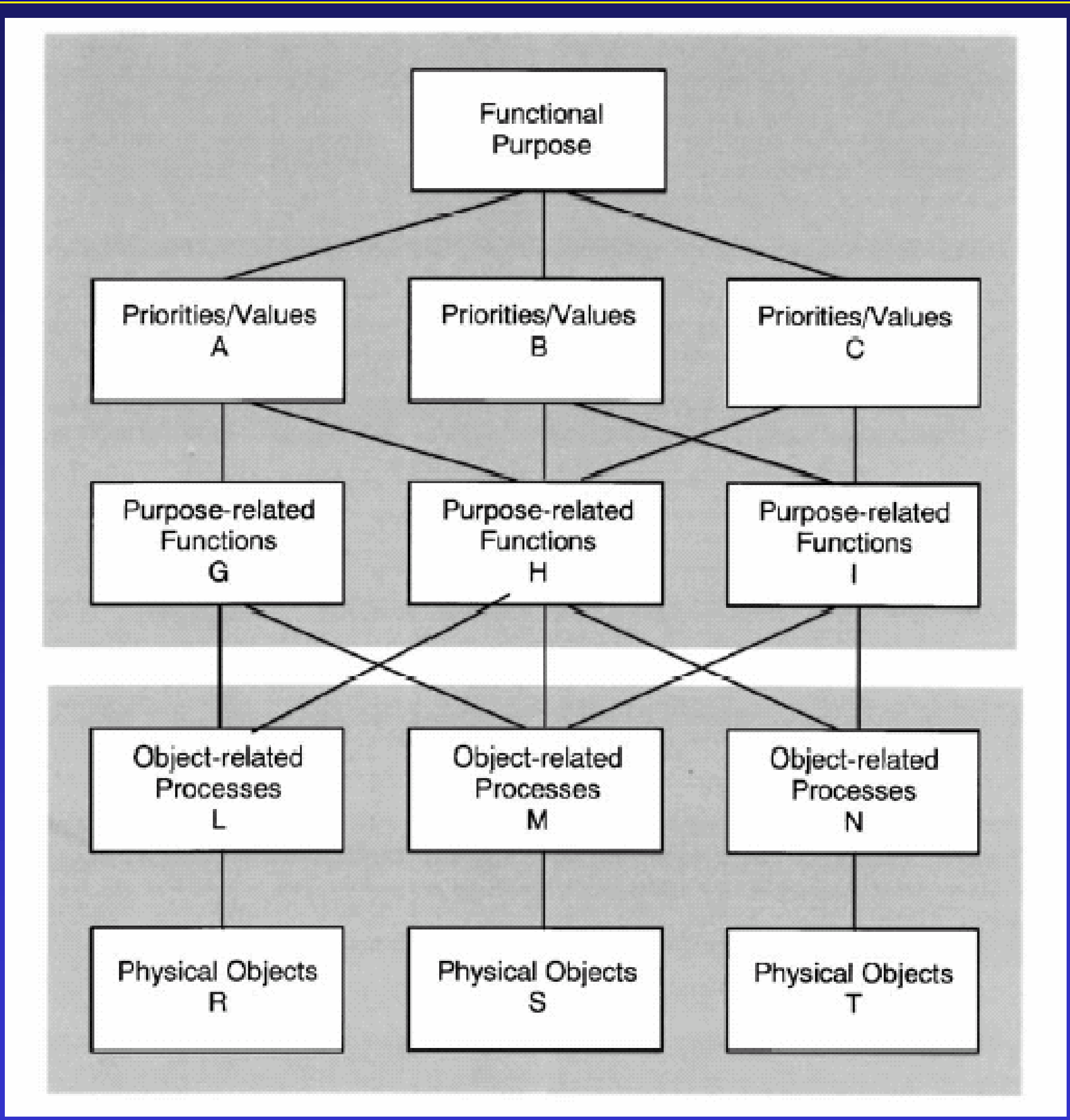
Another View of Task-driven Nature of "Situation Elements" *



* Ivanov, D.A. et al, "Fundamentals of Tactical Command and Control: A Soviet View", Soviet Military Thought, No. 18, translated and published by USAF, 1977

Assessing User/Task Information Needs

Layered Approach to Cognitive Work Analysis



* Reising, D. , “Work domain analysis and sensors I: principles and simple example”, Int. J. Human-Computer Studies (2002) 56, 569–596)
Rasmussen, J., Pejtersen, A. M. & Goodstein, L. P. (1994). Cognitive Systems Engineering. New York: John Wiley & Sons.

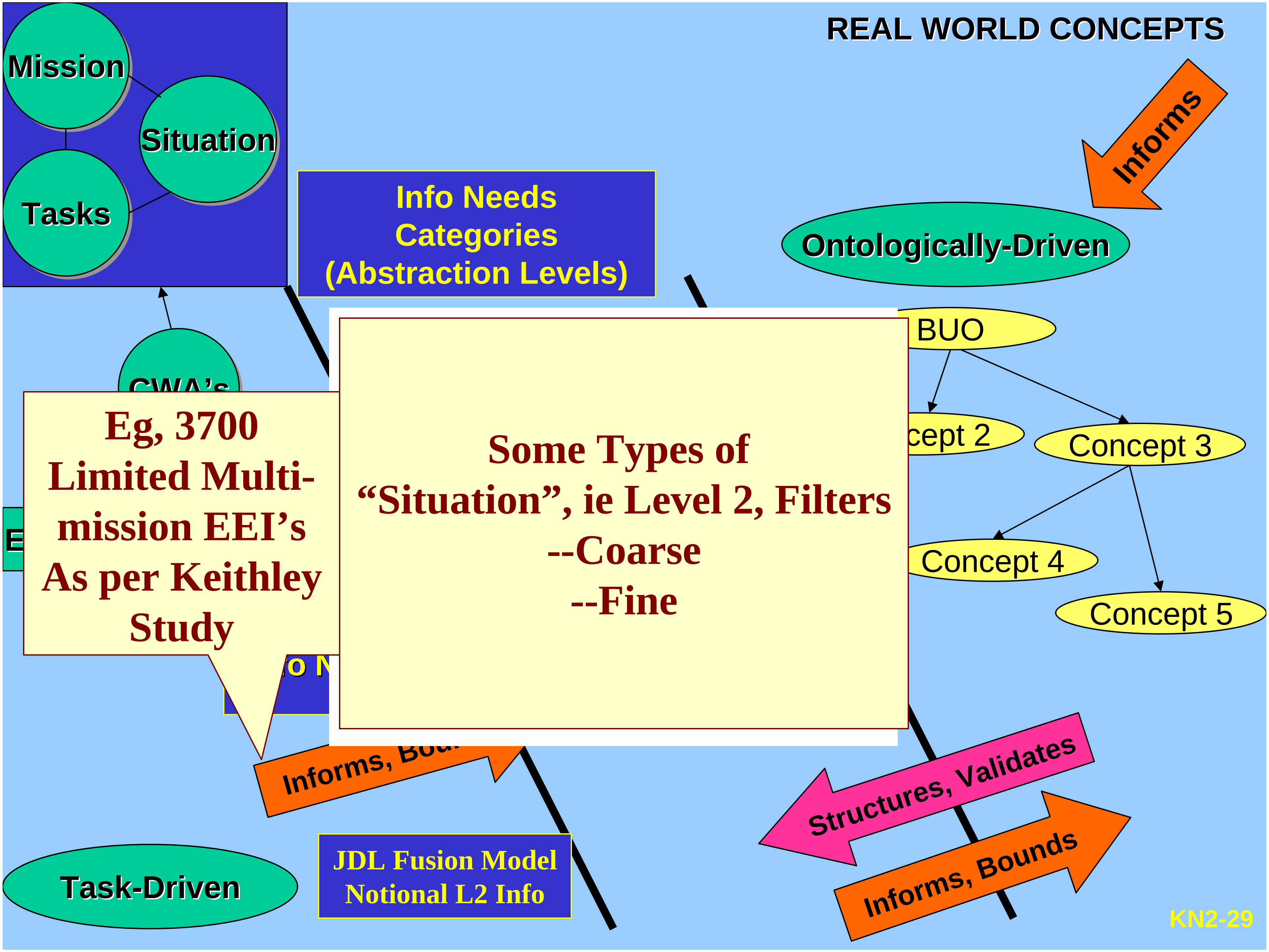
Ontological Construction Ideally Derived from a Synergistic Relation with User Information Needs

1) User/Task Information Needs <u>INFORM and BOUND</u> Ontological Structure.

- Top-down and Bottom-up Construction
- Empirically Driven
- Reflects Epistemically-driven (cognitive) Info Needs
- Possibly developed from Cognitive Work Analysis techniques
- Sometimes developed as ad hoc Taxonomies, Dictionaries

2) Ontological Development <u>STRUCTURES and VALIDATES</u> One's Common-Sense, Non-formal Abstractions of the World.

- Generally Top-down Construction
- Rationally Driven
- Reflects Epistemically-Independent Structure of the Existing World


REAL WORLD CONCEPTS
Informs
Mission
Situation
Tasks
Info Needs
Categories
(Abstraction Levels)
Ontologically-Driven
BUO
Concept 3
Concept 4
Concept 5
Eg, 3700
Limited Multi-
mission EEI's
As per Keithley
Study
Some Types of
"Situation", ie Level 2, Filters
--Coarse
--Fine
Structures, Validates
Informs, Bounds
Task-Driven
JDL Fusion Model
Notional L2 Info
KN2-29

“Admission” still a Problem

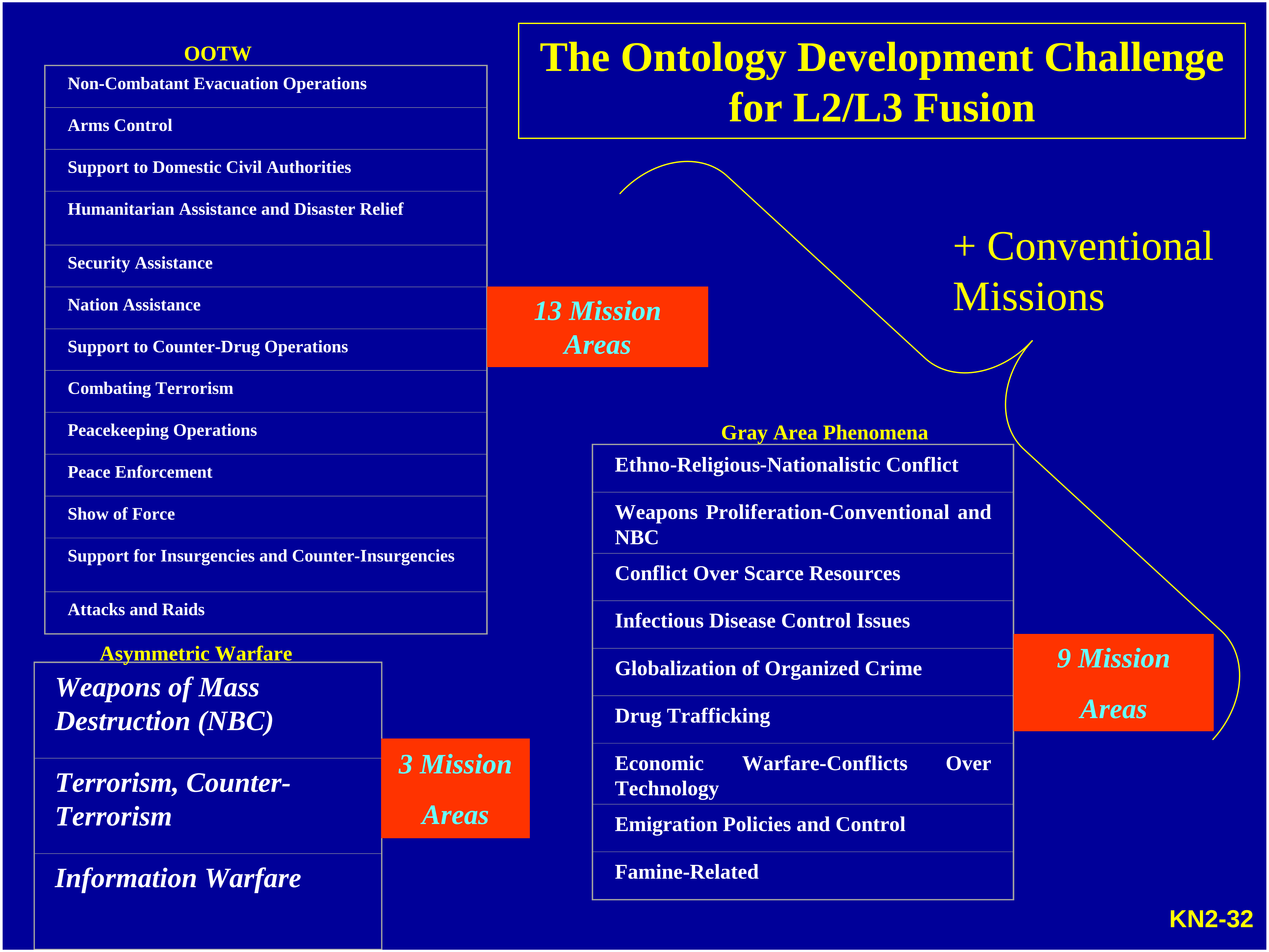
- Is the ad hoc notion of “Situation” (since the theories on “situation” don’t help us much in regard to our applications) sufficient as a “Coarse Filter” to bound what we will attribute to Level 2?
- How else to do it?
- Reexamine CCIR structure and partition to Fusion Levels in some other way?
- We need to specify “L2 Filters”

Scope of the Ontology-Development Task

- ***Conventional Threats***
  - Lethality
  - Intent
  - Opportunity
  - Largely deductive
- ***Asymmetric Threats***
  - Lethality = ?
  - Intent : how to estimate?
  - Opportunity: how to estimate?
  - Deductive vs Inductive approaches

~??? Mission Areas

~25 Mission Areas

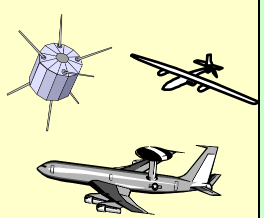

The Ontology Development Challenge for L2/L3 Fusion
OOTW
Non-Combatant Evacuation Operations
Arms Control
Support to Domestic Civil Authorities
Humanitarian Assistance and Disaster Relief
Security Assistance
Nation Assistance
Support to Counter-Drug Operations
Combating Terrorism
Peacekeeping Operations
Peace Enforcement
Show of Force
Support for Insurgencies and Counter-Insurgencies
Attacks and Raids
13 Mission Areas
+ Conventional Missions
Gray Area Phenomena
Ethno-Religious-Nationalistic Conflict
Weapons Proliferation-Conventional and NBC
Conflict Over Scarce Resources
Infectious Disease Control Issues
Globalization of Organized Crime
Drug Trafficking
Economic Warfare-Conflicts Over Technology
Emigration Policies and Control
Famine-Related
9 Mission Areas
Asymmetric Warfare
Weapons of Mass Destruction (NBC)
Terrorism, Counter-Terrorism
Information Warfare
3 Mission Areas
KN2-32

Other Aspects of L2 Scientific Foundations

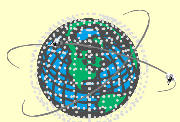
How is Data Fusion Done?

--Extensions of conventional (single-source) methods

--New, creative techniques specially designed for IF



- Intel Sources
- Air Surveillance
- Surface Surveillance
- Space Surveillance



L0: Sub-Object Association/ Correlation

•Combinatoric Optimization

•Numerical/Statistical Estimation Techniques

L1:

Association/ Correlation

•Combinatoric Optimization

Object Refinement

•Numerical/Statistical Estimation Techniques

•Pattern Recognition Techniques

L2: Situation Refinement

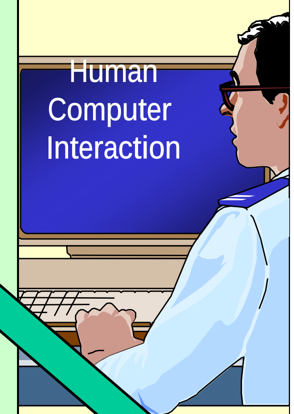
- Numerical/Statistical Estimation Techniques
- Knowledge-based, Symbolic Techniques

L3: Impact Assessment

- Numerical/Statistical Estimation Techniques
- Knowledge-based, Symbolic Techniques

L4: Adaptive Control Sensor

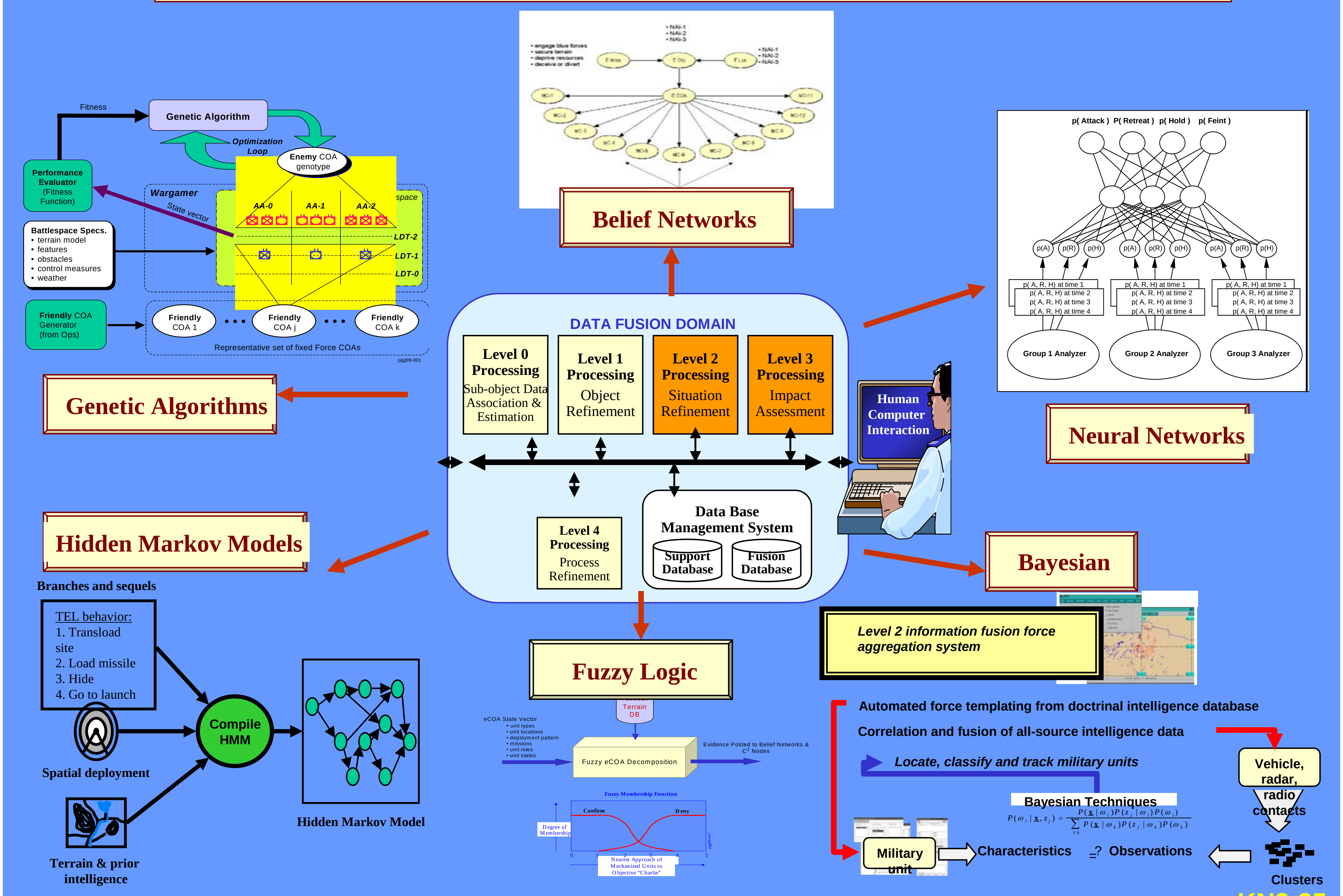
- Source Management; Info-theoretic Techniques
- Process Adaptation; Control-theoretic Techniques



• Not very specific

• Vague in defining scientific foundations

Quantitative Approaches to L2,3 Information Fusion



KN2-35

Scientific Foundations: Possibly-Relevant Theories for L2

- Ontology is one of them—the needed Existential Theory
- What else?
  - Theories of Situations
    - Situational Theory
    - Situation Semantics
    - Situational Calculus
  - Theories of Behaviors (and Tactics as appropriate)
  - Theories about Intent
  - Theories about Aggregations
  - Theories about Context
  - Theories about Relationships as defined in the Ontology

Searching the Literature:

Scientific methods for, Theories about
"Situations"

Classifying Situations *

- Vendler classified situations into four classes:
  - **Activities:** run, push (a cart).
    - Not time-bounded
  - **Accomplishments:** run a mile, draw a circle.
    - Spans an interval and has an end-point (telicity; tending toward an end-point)
  - **States:** know, love.
    - Static; persist over time
  - **Achievements:** find, recognize, spot.
    - spontaneous

* Vendler, Z. (1957). “Verbs and times”, *The Philosophical Review*, 66(2):143ñ160.
* Ismail, H.O., “Reasoning and Acting in Time”, PhD Dissertation, Univ at Buffalo, 2001

Another Classification of Situations *

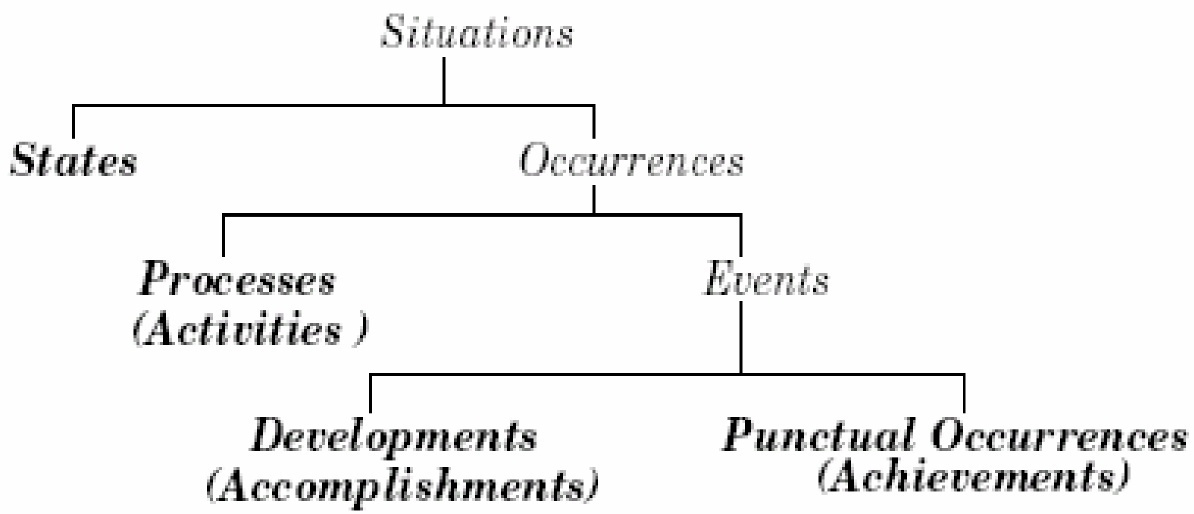


Figure 2.1: Mourelatos' classification of situation types.

* Mourelatos, A. P. D. (1978). “Events, processes, and states”, *Linguistics and Philosophy*, 2:415ñ434
* Ismail, H.O., “Reasoning and Acting in Time”, PhD Dissertation, Univ at Buffalo, 2001

Another Classification of Situations *

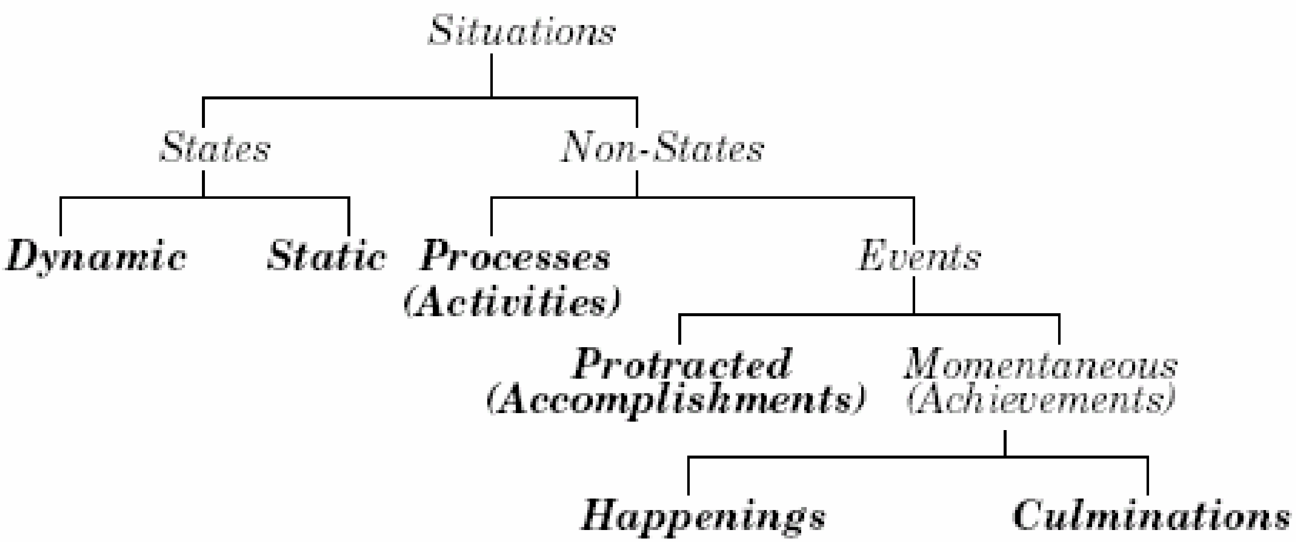


Figure 2.2: Bach's classification of situation types.

* Bach, E. (1986). "The algebra of events", *Linguistics and Philosophy*, 9:5ñ16.
* Ismail, H.O., "Reasoning and Acting in Time", PhD Dissertation, Univ at Buffalo, 2001

Another Classification of Situations *

	EVENTS		STATES
	atomic	extended	
+conseq	**CULMINATION** recognize, spot, win the race	**CULMINATED PROCESS** build a house, eat a sandwich	understand love, know resemble
−conseq	**POINT** hiccup, tap, wink	**PROCESS** run, swim, walk, play the piano	

Figure 2.3: Moens and Steedman's classification of situation types.

- **Shows relationship between situation-types via internals of event-structures**
- **Events made up of: preparatory stage, a culmination, a consequent stage**

* Bach, E. (1986). "The algebra of events", *Linguistics and Philosophy*, 9:5ñ16.
* Ismail, H.O., "Reasoning and Acting in Time", PhD Dissertation, Univ at Buffalo, 2001

Dimensions of situation-types*

- Durative-punctual
  - Consuming time or not
- Telic-atelic
  - Having an end-point or not
- States and non-states
  - Static, dynamic

* Ismail, H.O., “Reasoning and Acting in Time”, PhD Dissertation, Univ at Buffalo, 2001

Situation Calculus

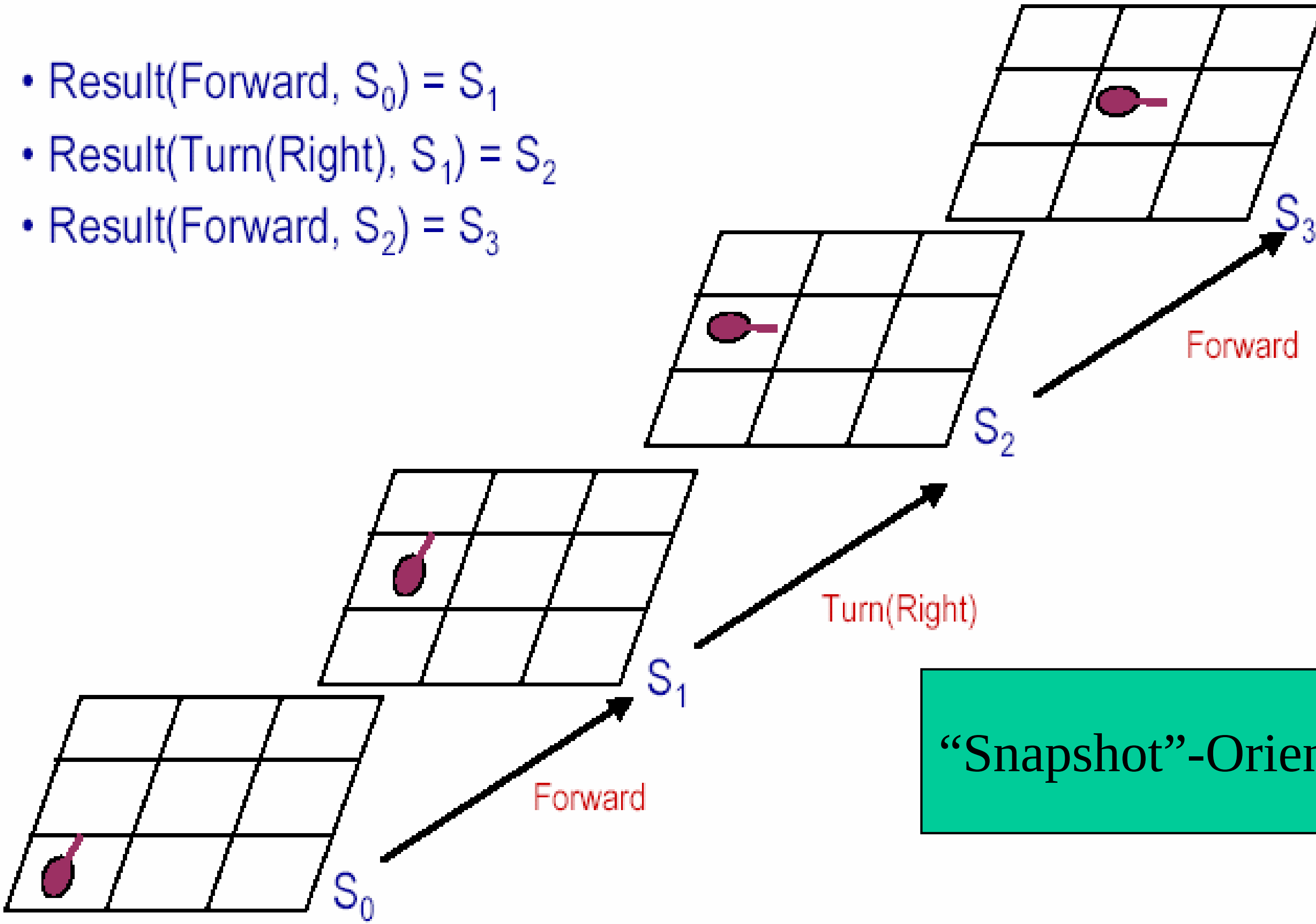
- Situation calculus:
  - Refers to a particular way of describing change in first-order logic
  - Conceives of world as consisting of a sequence of *situations*, each of which is a snapshot of the state of the world

- All relations/properties of world that can change over time:
  - Specify extra situation argument to predicate
  - Instead of: At(agent, location)
  - Indicate: At(agent, location, S_i), where S_i is a particular situation, or point in time

- Represent how world changes from one situation to next:
  - Result(Forward, S_0) = S_1
  - Result(Turn(Right), S_1) = S_2
  - Results(Forward, S_2) = S_3

Example of World Represented by Situation Calculus

- Result(Forward, S_0) = S_1
- Result(Turn(Right), S_1) = S_2
- Result(Forward, S_2) = S_3



“Snapshot”-Oriented

Science of Behaviors

- **Ethology** is the comparative study of behavior
- In a general way it attempts to discover and explain generalizations covering the behavior of organisms.
- However, Ethological theory focus on causes and adaptive value of behavior considering both evolutionary history and social context –good for some problems (eg terrorism?) but not all

Theories About “Behavior” *

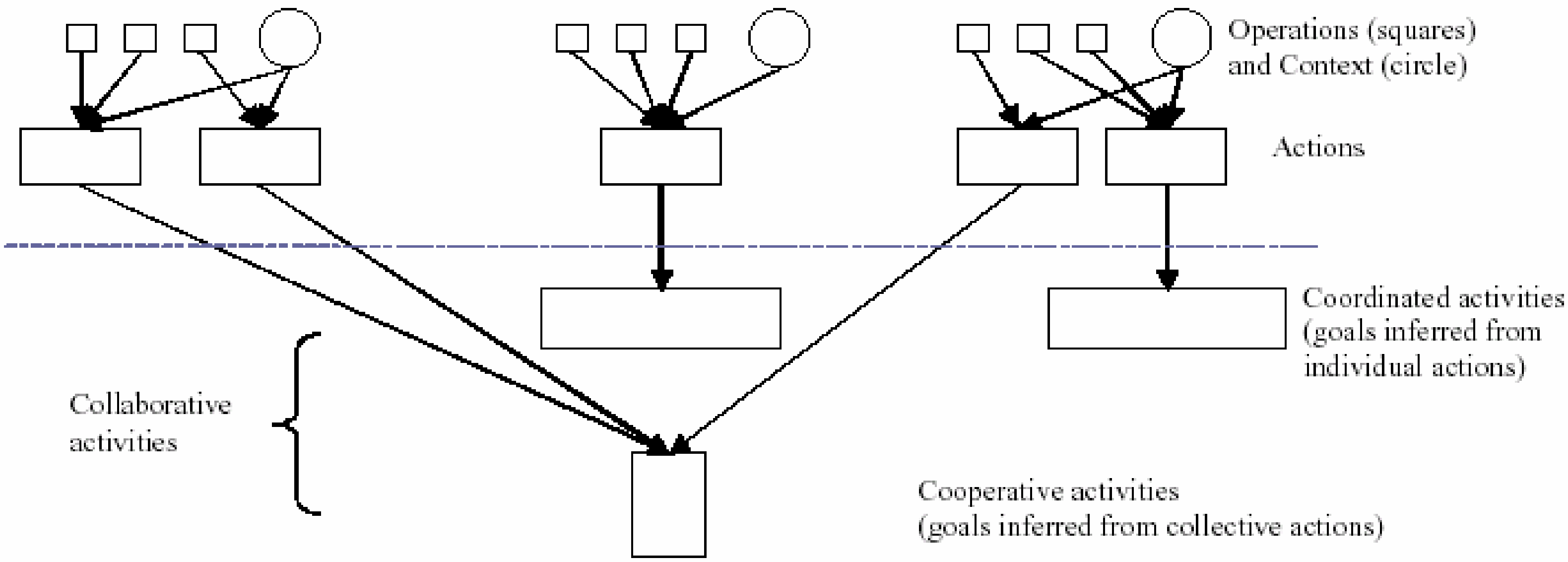


Figure 1 - Composition and organization of collaborative activities

Suggest 3 components:

--coordinated activities

--collaborative activities

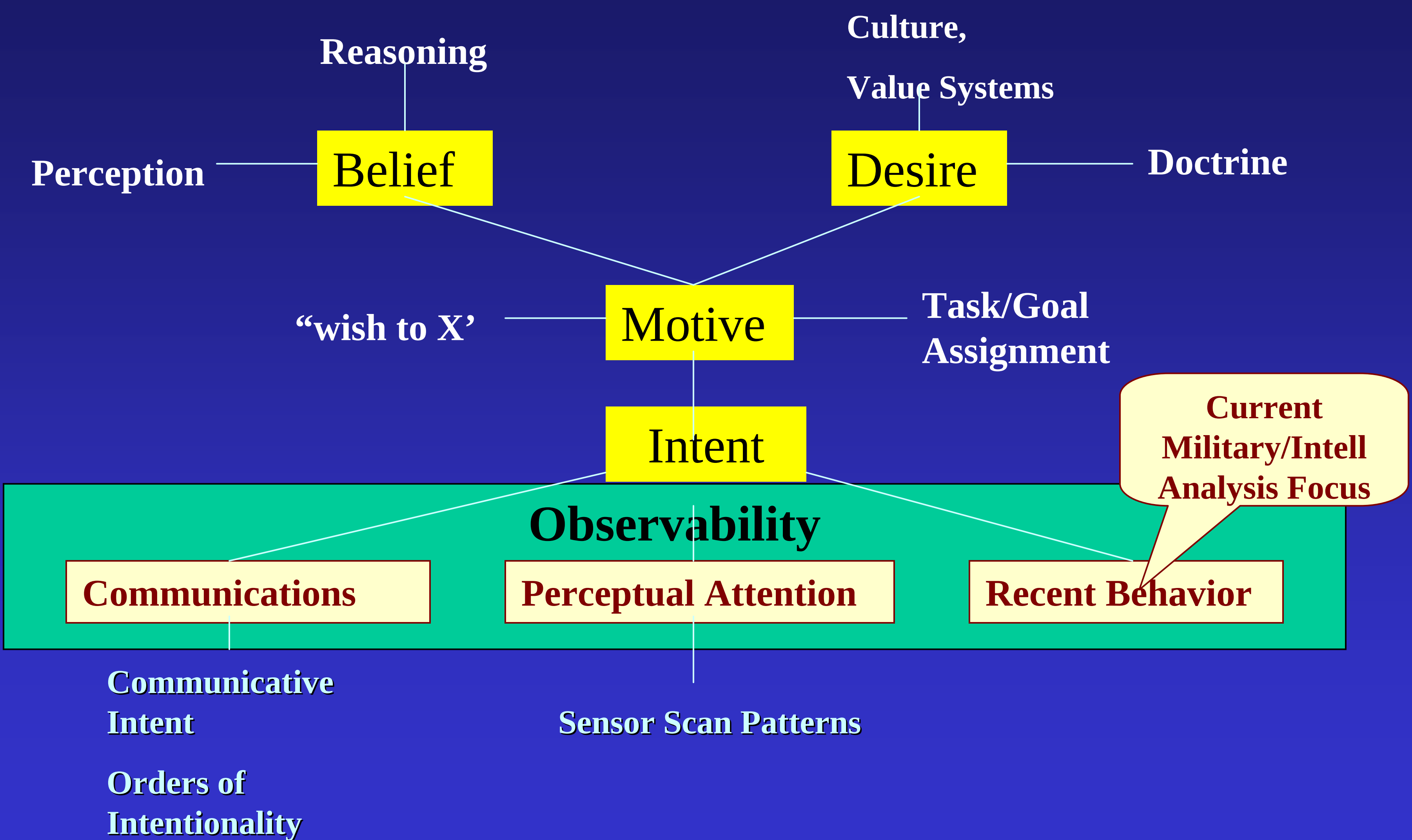
--cooperative activities

* Franke, J., et al” Enhancing Teamwork through Team-level Intent Inference” LMCO ATL Paper, http://www.atl.external.lmco.com/overview/papers/997.pdf

Notions of “Behavior” and “Role”

- ***Behavior:*** *A collection of actions with a set of constraints on when they may occur...*
- ***Role:*** *An abstraction of the behavior of an object that consists of a subset of the interactions of that object together with a set of constraints on when they may occur. A role always belongs to a specific larger behavior that involves other roles, called a* ***collaborative behavior****.*

Theories and Modeling of Intent



Llinas, J and Deutsch, R., "Perspectives of Intent from Various Bodies of Literature and Perspectives for Developing New Models of Intention Estimation And for the Development of Decision Aids", CMIF Report 2-99, Feb 1999

Theories of Groups, Teams, Coalitions, etc
-Adaptive Behaviors-

- There is a huge literature on Group Behavior; some references:
  - "Designing and Understanding Adaptive Group Behavior" (1995) M. J. Mataric, Brandeis Univ
  - "Collaborative Plans for Complex Group Action." Grosz, B.and Kraus, S., In Artificial Intelligence. 86(2), pp.
    269-357, 1996
- The Intelligent Agent literature is perhaps a better basis for researching ideas and concepts regarding multi-agent behavior as it might apply to Information Fusion applications
- Theories:
  - **Teamwork:** see Tambe, Cohen & Levesque, etc
  - **Coalitions:** Klusch, M., Gerber, A. (2002): Dynamic Coalition Formation Among Rational Agents. Journal IEEE Intelligent Systems, 17(3), IEEE Press.

Theories and Notions of Context *

- Llinas: Context is an epistemological matter, not an existential matter
- “One area almost totally devoid of systematic research is that of context”.
- “Primary KBS maintenance issue derives from lack of contextual-interpretation capability”
- Jansen reviews various literature—all offering rather vague characterizations; most specific was:
  - “Mittal and Paris (1993) identify the following five aspects of context, ….: the problem solving situation; the participants involved; the mode of interaction in which the communication is occurring; the discourse taking pace; and the external world”.
  - Mittal VO & Paris CL, *Context: Identifying its Elements from the Communication Point of View*, in Proceedings of the IJCAI'93 Workshop on "Using Knowledge in its Context", France 1993, pp87-97

* Jansen, R., “CONTEXT: A REAL PROBLEM FOR LARGE AND SHAREABLE KNOWLEDGE BASES”, CSIRO Division of Information Technology, North Ryde, NSW 2113, AUSTRALIA

Semantic Theories *

(nature of relationships to be studied at DSTO; pursuing formal semantic theories)
"symbols capable of describing military action"

Social:	group, ally, enemy, neutral, own, possess, invite, offer, accept, authorise, allow.
Intentional:	individual, routine, learnt, achieve, perform, succeed, fail, intend, desire, belief, expect anticipate, sense, inform, effect, approve, disapprove, prefer.
Functional:	sense, move, strike, attach, inform, operational, disrupt, neutralise, destroy.
Physical:	land, sea, air, outer_space, incline, decline, number, temperature, weight, energy.
Metaphysical:	exist, fragment, identity, time, before, space, connect, distance, area, volume, angle.

Figure 7. Semantic theories for FOCAL.

In my view I see these as helpful toward identifying relationship-types—ie relationship-types within each semantic theory-class

But I am not an Ontologist

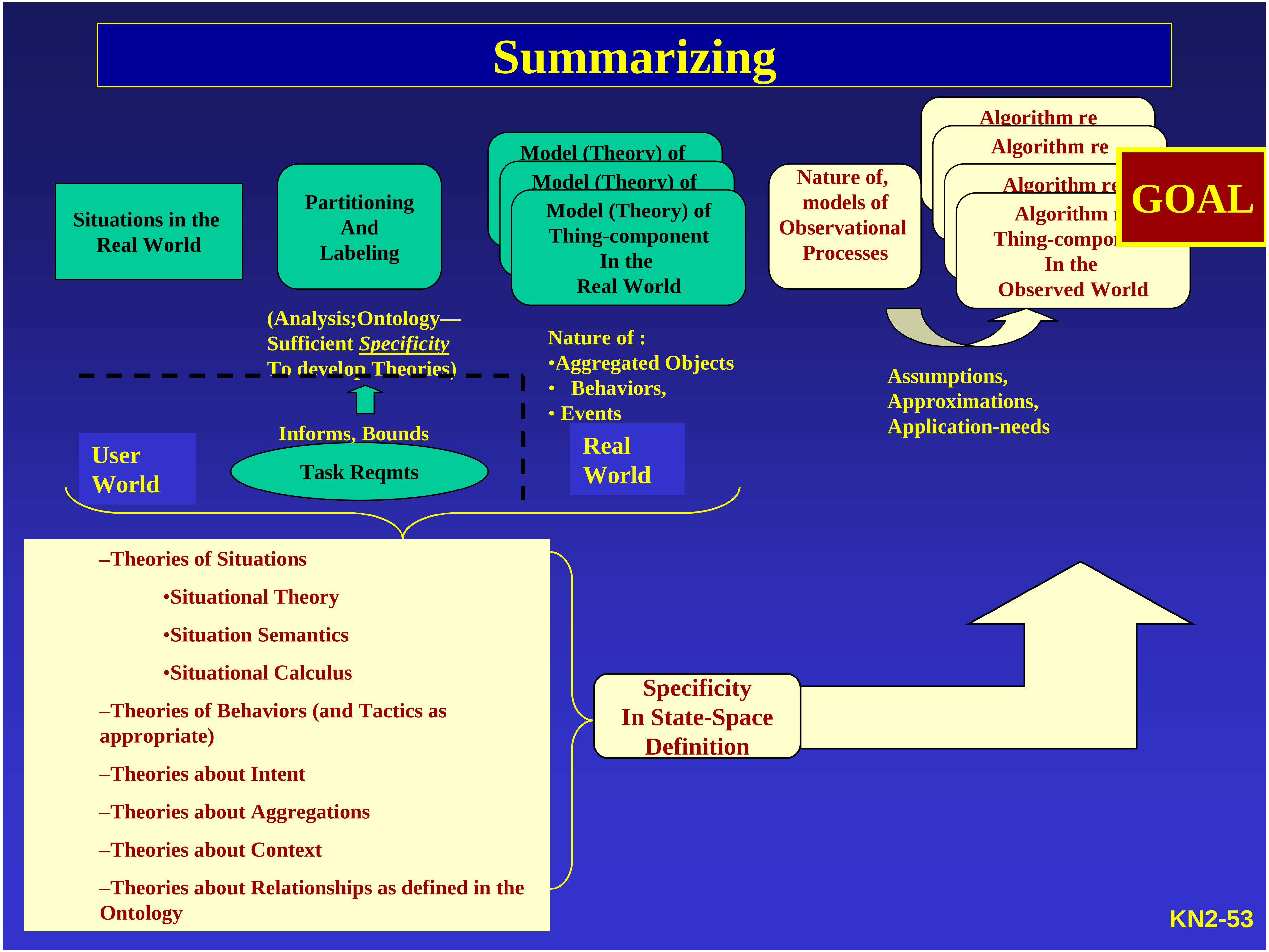
*** D. Lambert, DSTO, FUSION2003**

Theories and Notions of Trust

Trust Attribute	**Characteristics**	**Basis for Trust Development**
Reliability	Repeated, consistent functioning	Conditioning
Robustness	Similar to Competence; good performance under varying problem conditions	Conditioning; often achieved with a small sample of cases (and potentially unwarranted)
Familiarity	Employment of familiar/friendly/natural procedures, terms, etc.	Inherited from the culture of the domain (or life experience); can be unwarranted, irrational
Understandability	Not the same as Familiarity or ease of use; supports formation of mental models and predictive framework	Some notion of "visibility" into inner processes. Distrust and alienation formed when inner workings not understood.
Explication of Intention	Not same as Understandability in that intention is *overtly stated*; Understandability allows *inferring* intent	Execution of actions per stated intent--in a sense, follow-up on intended/stated actions
Usefulness	Classical notion of utility	From use of a "focused" or "directed" system that supports assigned work.
Dependence	Reliance on system to support human performance	Can be "Catch-22" type relationship--a type of *forced* trust on a system you (must) depend on

All are Design Factors

Bisantz, A., et al, "Empirical Investigations of Trust-related System Vulnerabilities in Aided, Adversarial Decision Making", CMIF Report, Jan 2000


Summarizing
Situations in the Real World
Partitioning And Labeling
(Analysis;Ontology— Sufficient Specificity To develop Theories)
Model (Theory) of
Model (Theory) of
Model (Theory) of Thing-component In the Real World
Nature of : •Aggregated Objects • Behaviors, • Events
Nature of, models of Observational Processes
Algorithm re
Algorithm re
Algorithm re
Algorithm r
Thing-compo
In the
Observed World
GOAL
Assumptions, Approximations, Application-needs
Informs, Bounds
Task Reqmts
User World
Real World
–Theories of Situations
•Situational Theory
•Situation Semantics
•Situational Calculus
–Theories of Behaviors (and Tactics as appropriate)
–Theories about Intent
–Theories about Aggregations
–Theories about Context
–Theories about Relationships as defined in the Ontology
Specificity In State-Space Definition
KN2-53